Remote and in Situ Optical Methodologies for Characterization of Ecosystem-level Physical and Biogeochemical Processes in the Great Lakes

Steven E. Lohrenz

Oscar M. E. Schofield

Gary L. Fahnenstiel

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Introduction

- Given the extensive coastline and diversity of coastal ecosystems, the Great Lakes region is particularly sensitive to change, both natural and anthropogenic

Introduction

- Because of the relatively small size and bounded nature of lakes, responses of lake ecosystems to changes in forcing may be more pronounced than in their more resilient oceanic counterparts
- As such, the Great Lakes may serve as a sentinel of changes occurring on larger scales

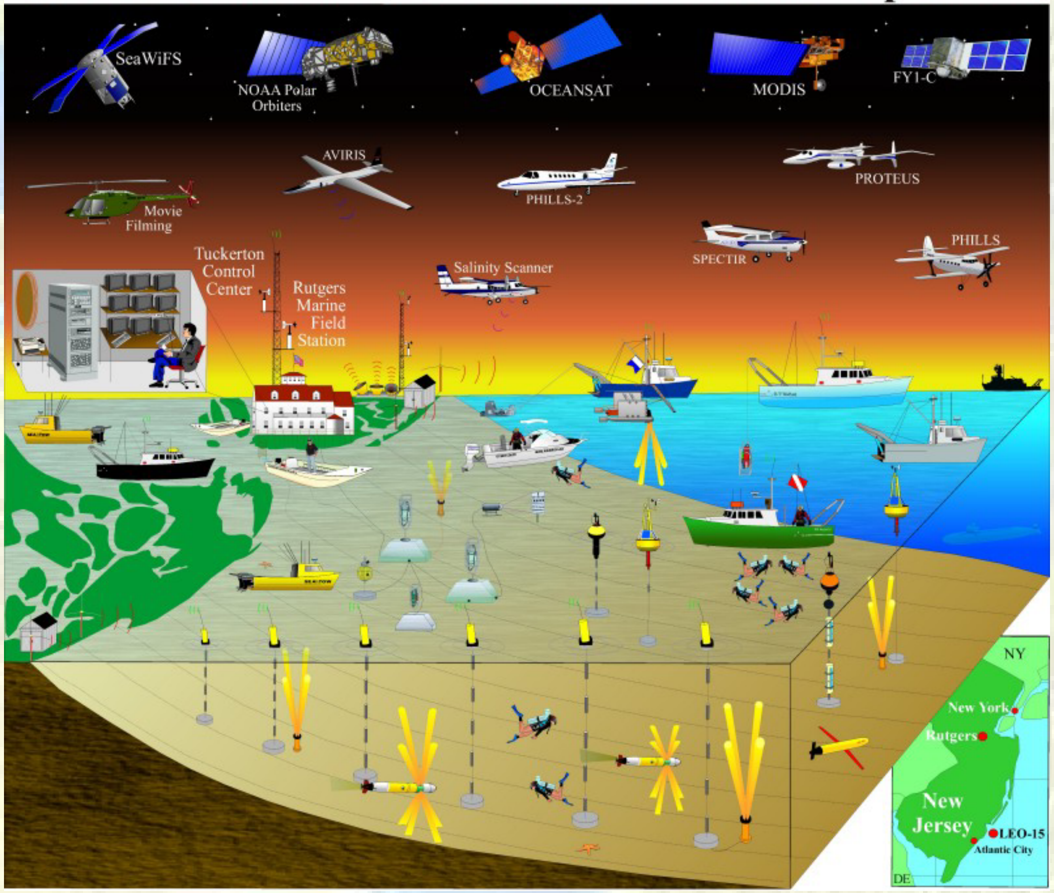
Introduction

- Our ability to detect and assess change in large-scale processes and dynamics associated with changing environmental forcing can be greatly enhanced by optical methods

Introduction

- Here, we consider the potential applications of remote and in situ optical methodologies for the study of ecosystem dynamics and associated physical and biogeochemical processes in the Great Lakes

LEO Instrumentation Used for the 2000-2001 Experiment



Introduction

- Examples are provided of various approaches that could be implemented in support of management needs for environmental decision-making related to the Great Lakes and their associated natural resources

Introduction

- Specifically, we examine the utility of optical measurements and analyses using available algorithms to:
  - trace inputs, transport and transformation of river-borne materials in coastal waters of the Great Lakes
  - characterize sediment distribution and transport, and sediment properties
  - track the occurrence and evolution of large-scale algal blooms
  - assess lake-scale temporal and spatial patterns in ecosystem processes such as phytoplankton biomass, primary production and community structure

Introduction

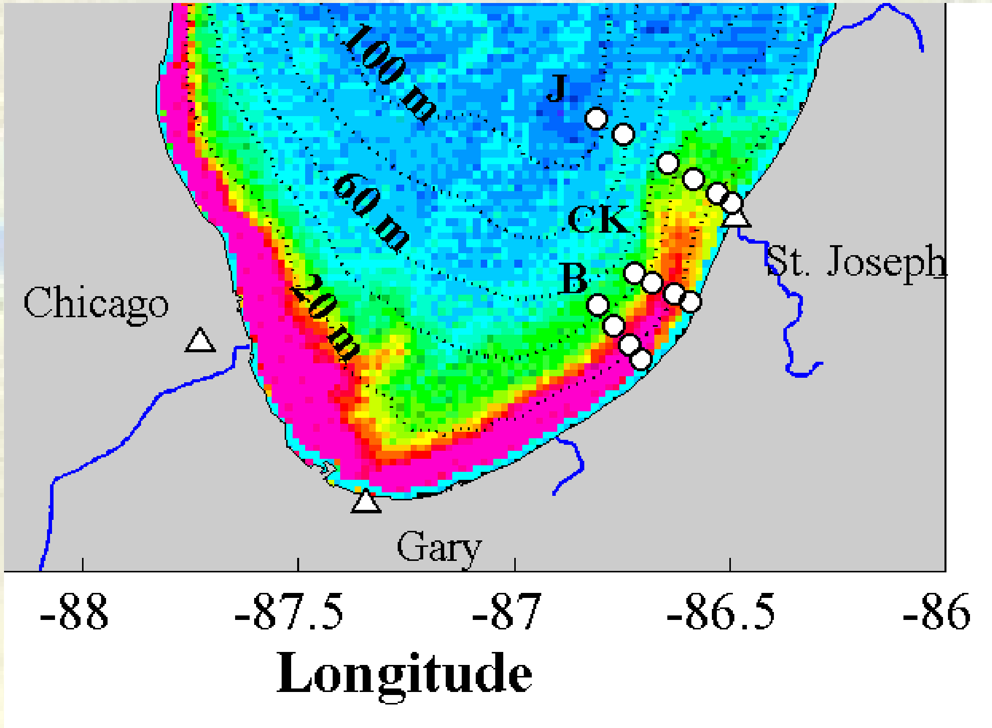
- Finally, we introduce several strawman themes for future research initiatives involving optical approaches in the Great Lakes

Examples

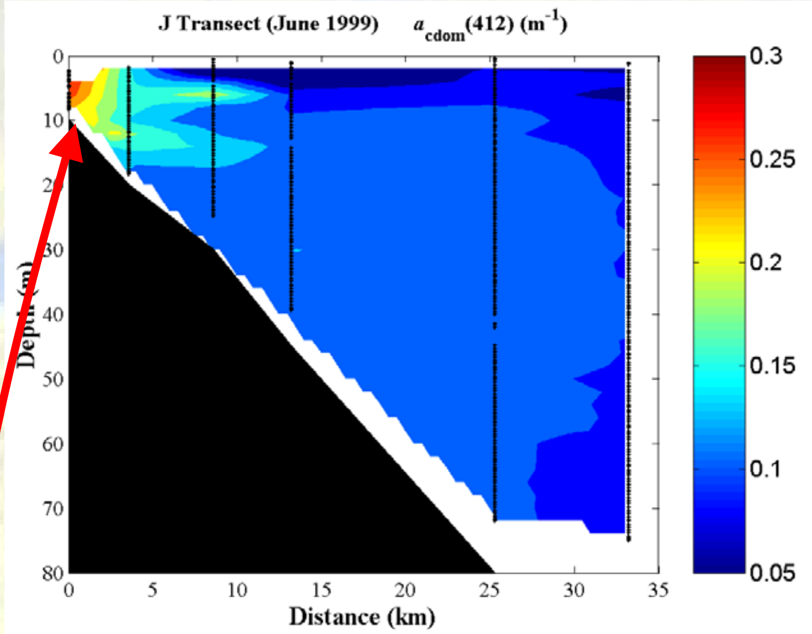
- Trace inputs, transport and transformation of river-borne materials in coastal waters of the Great Lakes
- Characterize sediment distribution and transport, and sediment properties
- Track the occurrence and evolution of large-scale algal blooms
- Assess lake-scale temporal and spatial patterns in ecosystem processes

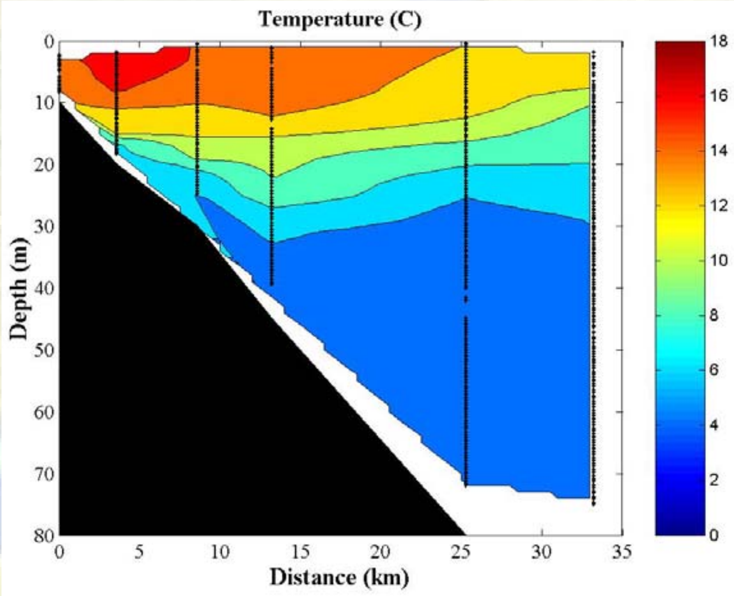
Tracing River-borne Material Fluxes – A Case Study

- Bio-optical properties were characterized in southeastern Lake Michigan during June 1999 and 2000
- Observations made during following the onset of summer stratification



Tracing River Inputs

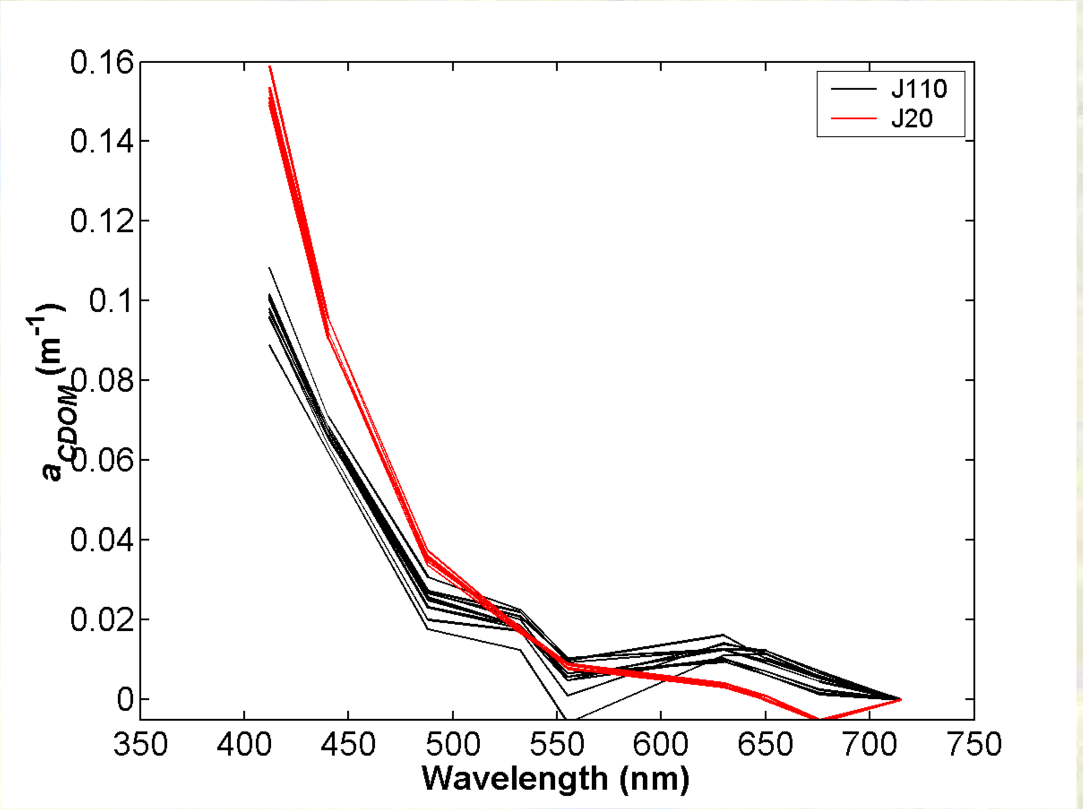




- Contour plots of CDOM and temperature off the St. Joseph River on June 4, 1999
- Warm waters from the St. Joseph River contributed to a localized area of distinct bio-optical properties, as characterized by high CDOM absorption values

Tracing River Inputs

- Low near-surface absorption values reflected photo-oxidative losses or advective inputs of low CDOM waters
- Exponential slope of CDOM spectrum provides information about photochemical degradation



Tracing River Inputs

- Previous studies have demonstrated enhanced primary and secondary productivity in the vicinity of the river outflow
- River inputs may also contribute to seasonal progression of the thermal bar, with implications for productivity
- Optical sensors may be used to monitor time-varying responses to river inputs

Examples

- Trace inputs, transport and transformation of river-borne materials in coastal waters of the Great Lakes
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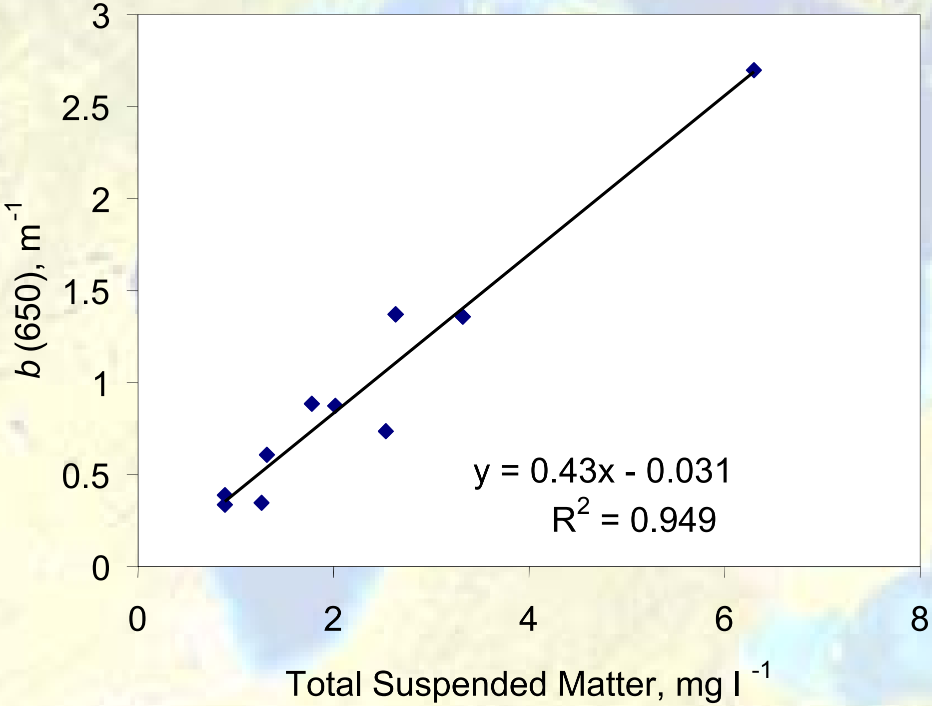
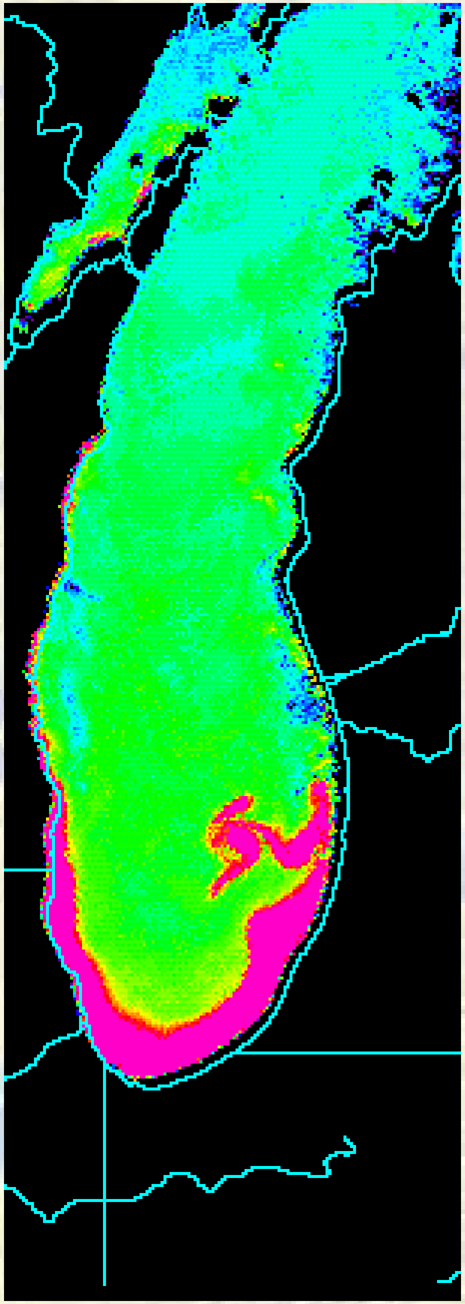
Sediment Resuspension and Transport

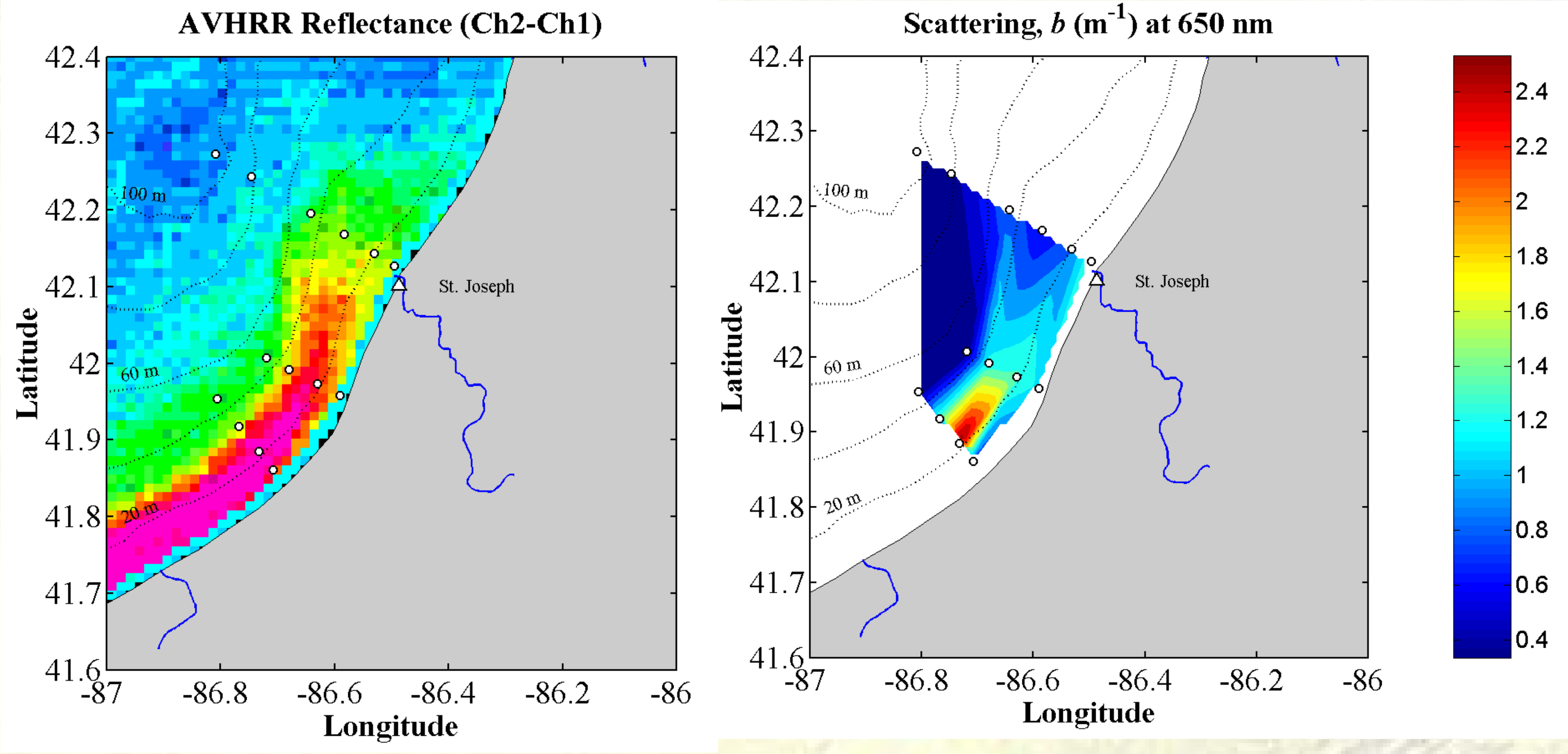
- Southeastern Lake Michigan – recurrent coastal sediment plume
- Strong correlation with scattering





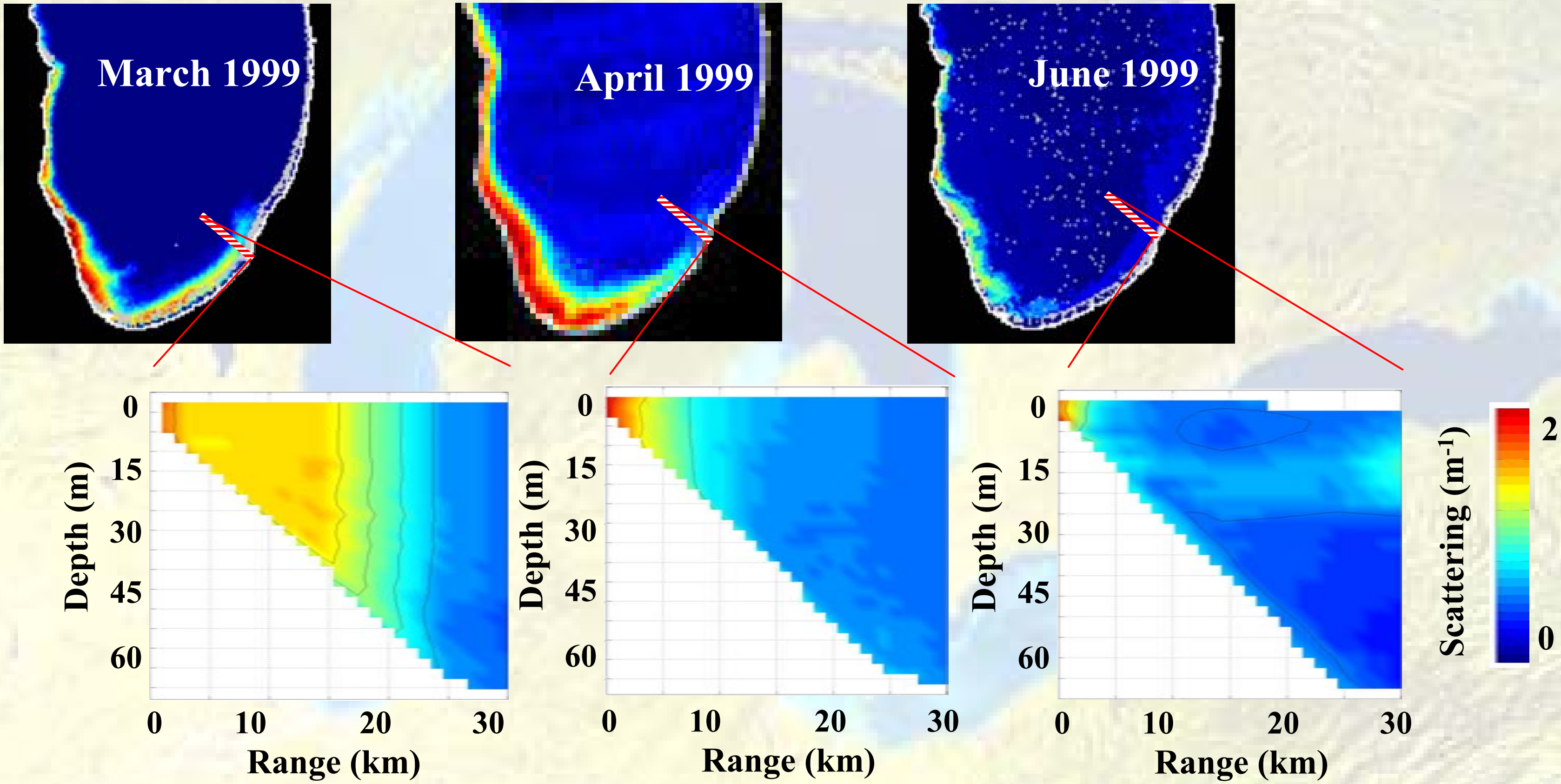
Sediment Resuspension and Transport

- In situ measurements of scattering provide validation of remotely sensed observations
- Provide higher spatial resolution



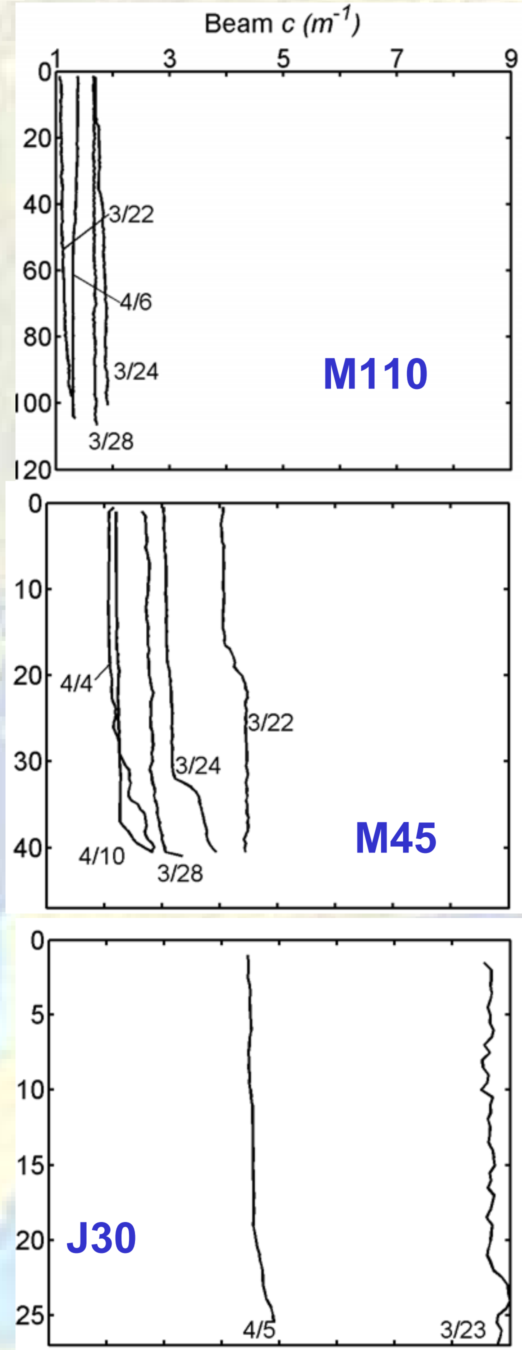
Sediment Resuspension and Transport

- **Temporal sequence of recurrent coastal plume (from Bergmann et al.)**



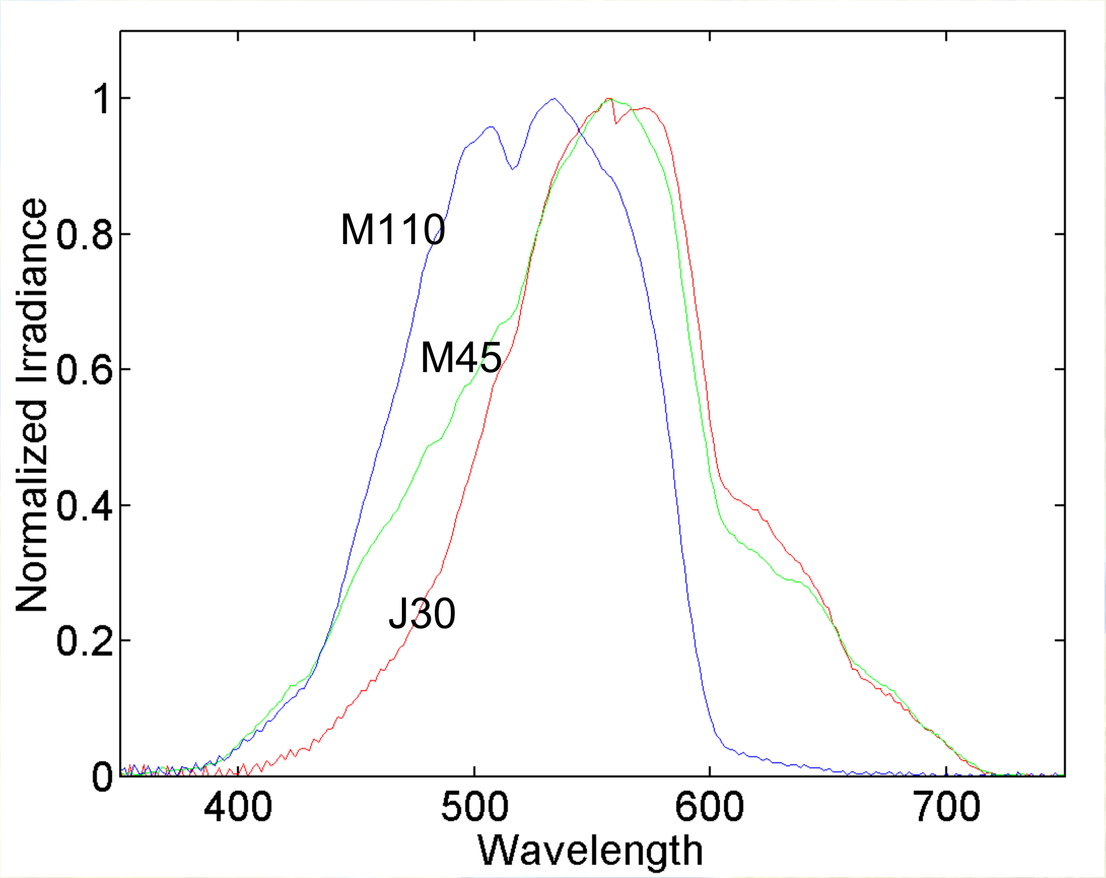
Sediment Resuspension and Transport

- **In situ optical measurements can provide information about:**
  - vertical structure to complement remotely sensed observations
  - particle size and refractive index (composition)



Influence of Sediment on Optical Conditions – Lake Michigan

- **Progressive shift toward red with increasing turbidity**
- **Contributes to phytoplankton and food web responses**



Examples

- Trace inputs, transport and transformation of river-borne materials in coastal waters of the Great Lakes
- Characterize sediment distribution and transport, and sediment properties
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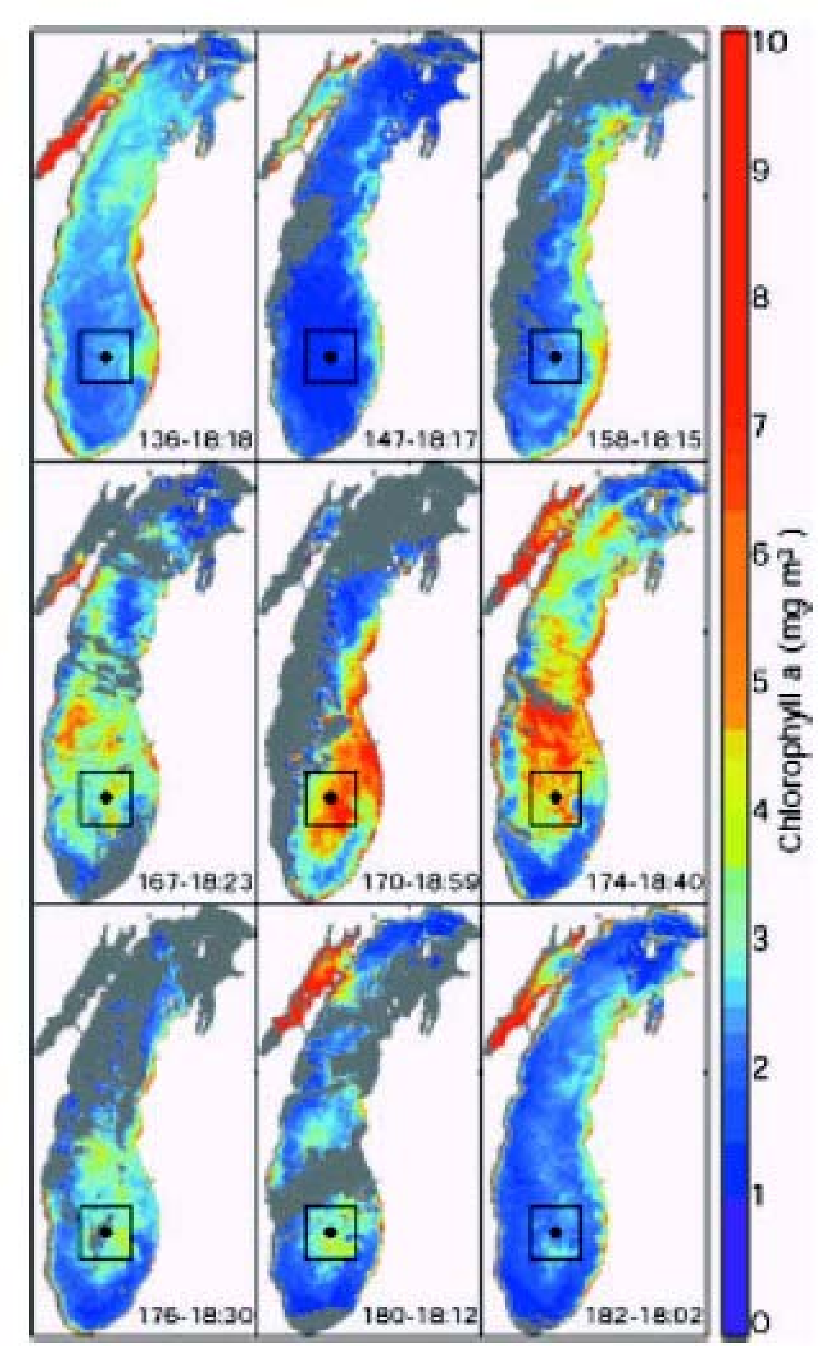
Large Scale Algal Bloom Events

- Algal bloom events evident in satellite imagery (from Lesht et al., 2002)
- Nuisance/toxic algal events
- Linkages to environmental forcing



Examples

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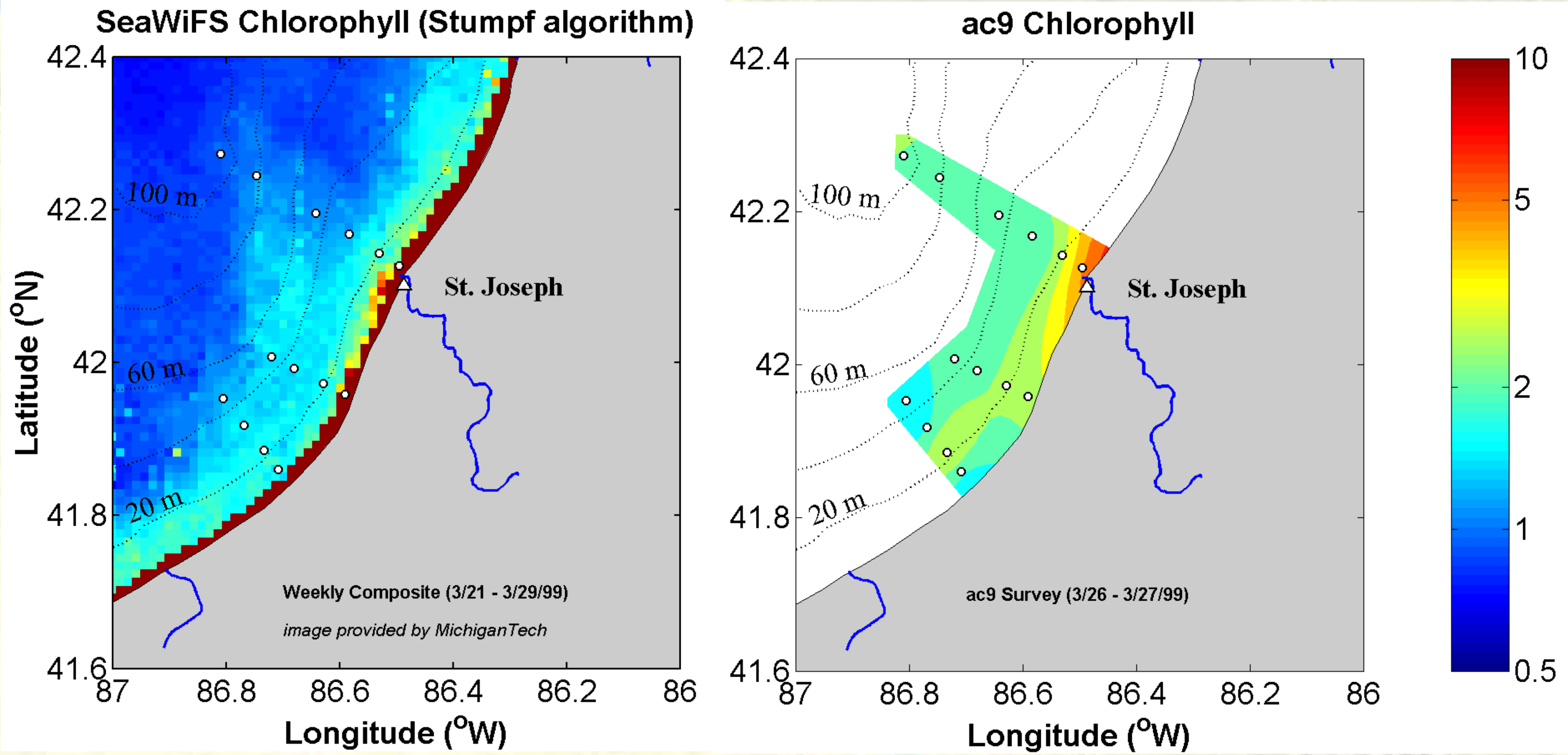
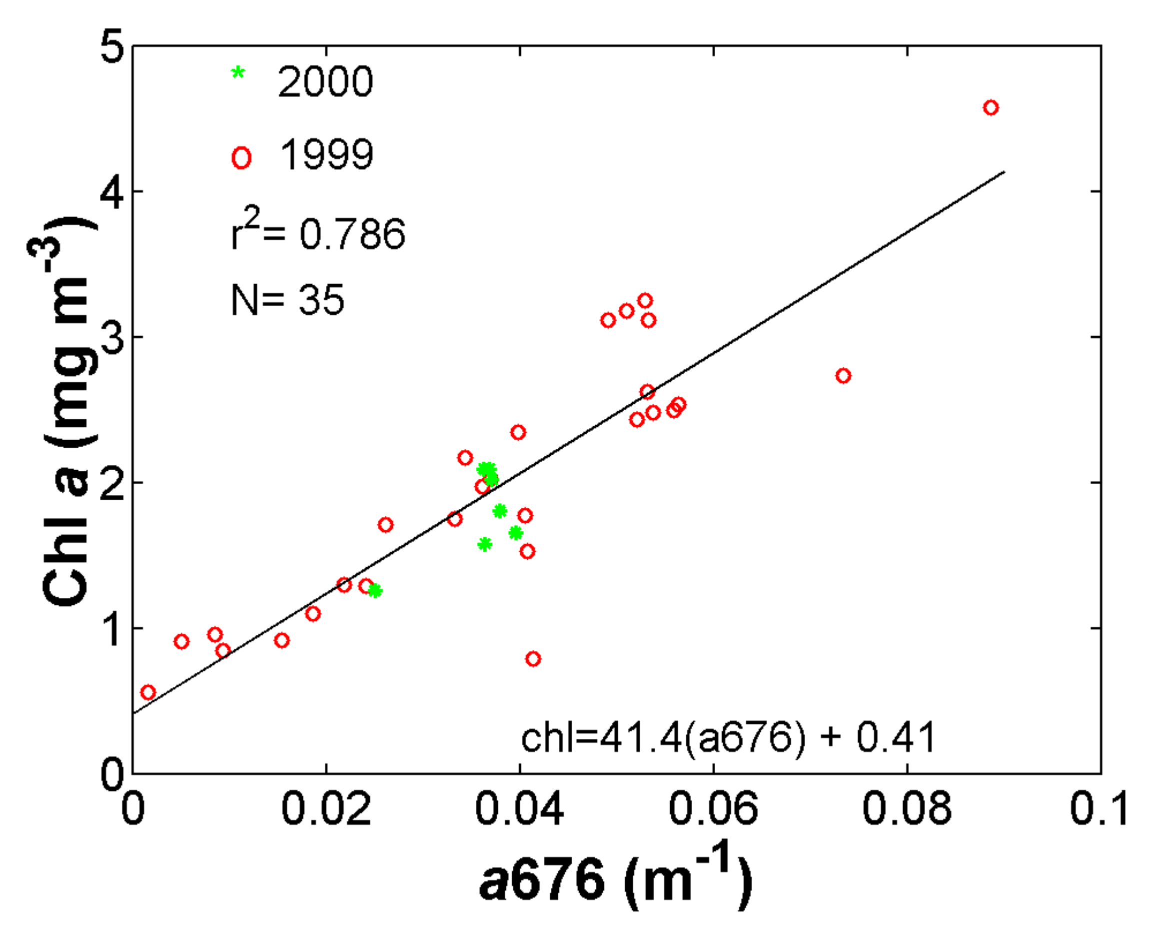
Ecosystem-level assessment of temporal and spatial patterns

- Chlorophyll biomass distributions



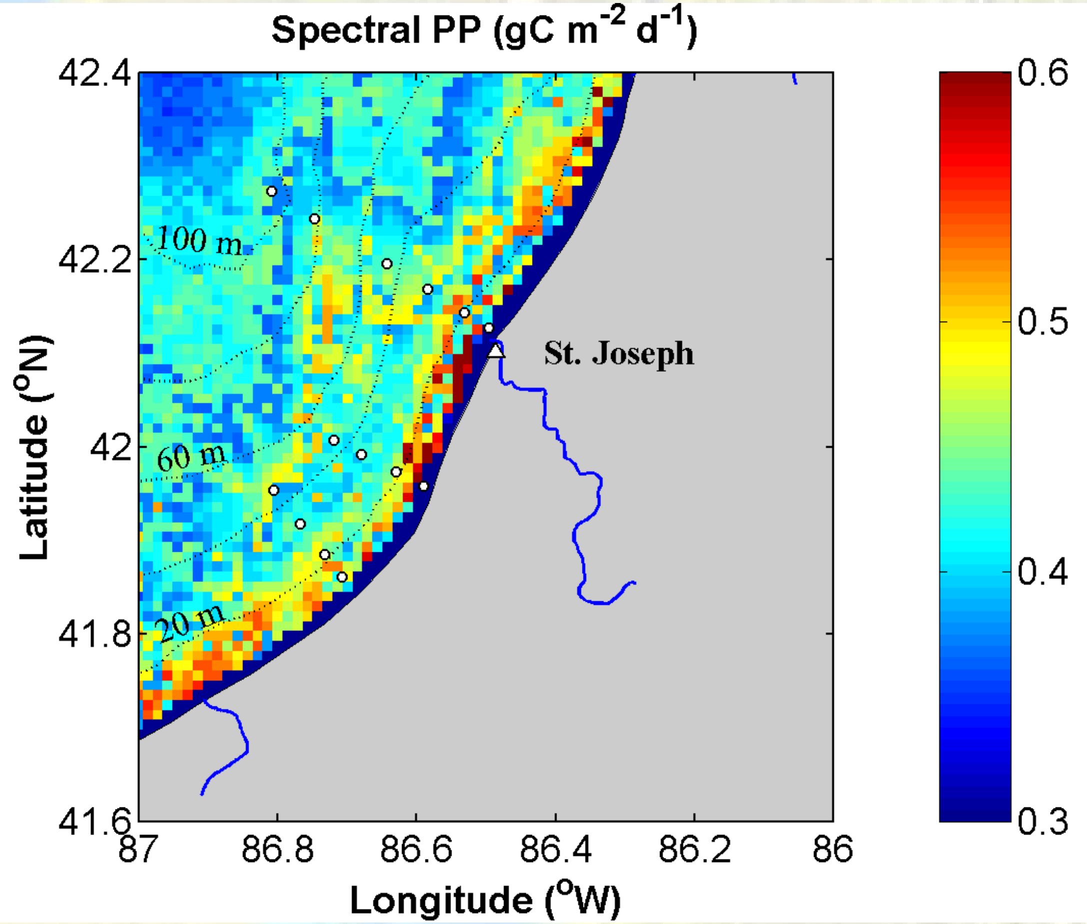
Ecosystem-level assessment of temporal and spatial patterns

- **Optical indices of chlorophyll**



Ecosystem-level assessment of temporal and spatial patterns

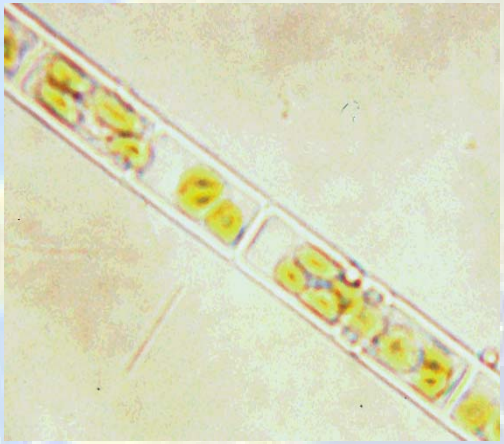
- **Satellite derived primary production – March 1998**



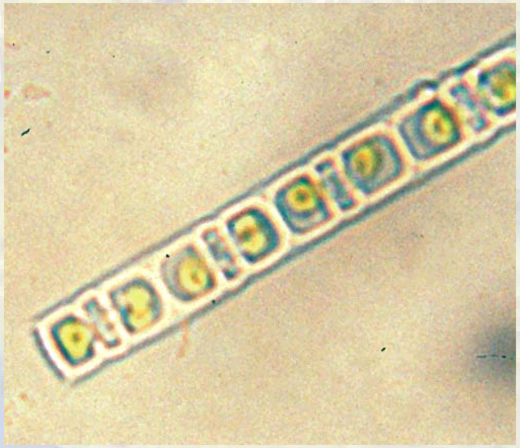
Optical Signatures of Phytoplankton Community Structure

- **Optically distinct phytoplankton taxa**

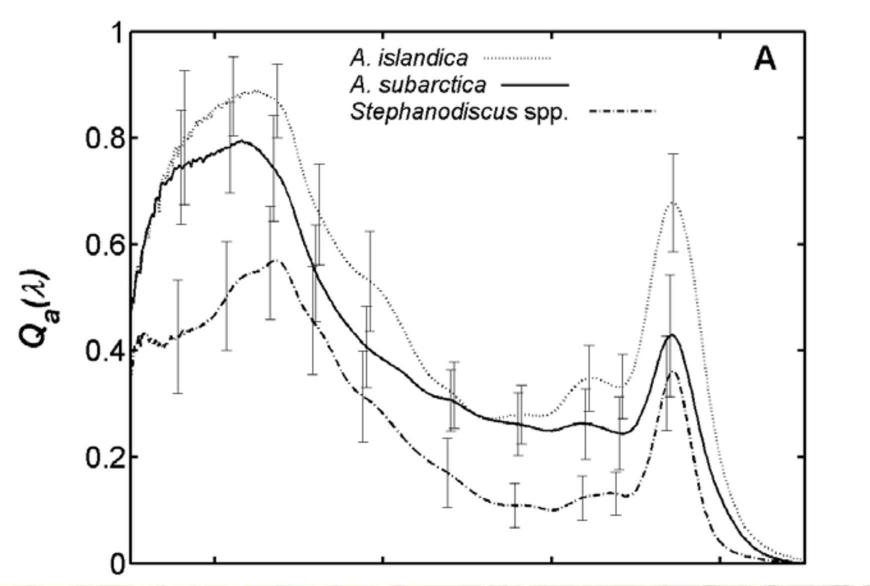
Aulacoseira islandica



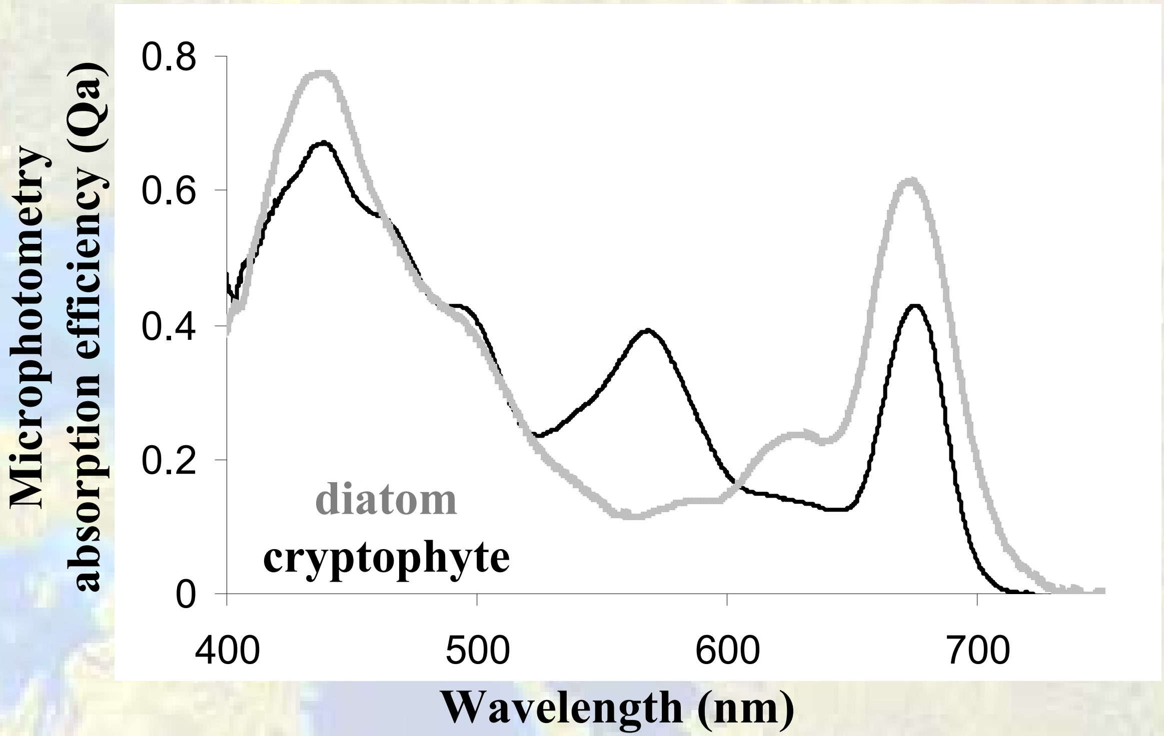
Aulacoseira subarctica

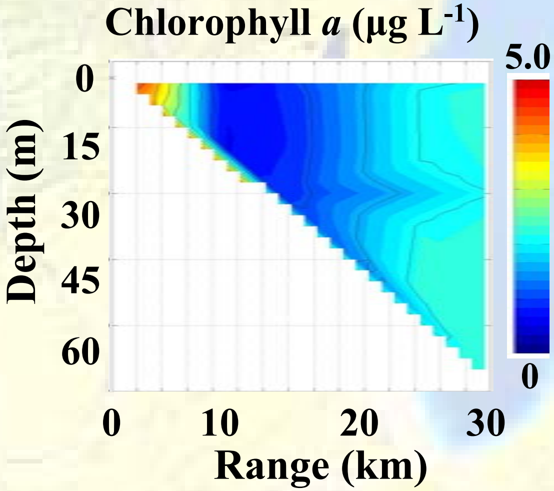


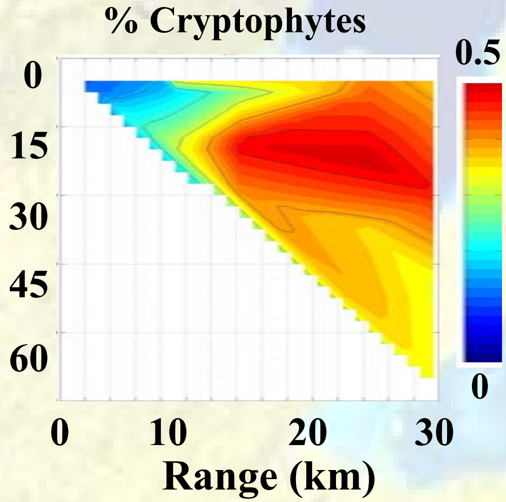
Stephanodiscus spp.

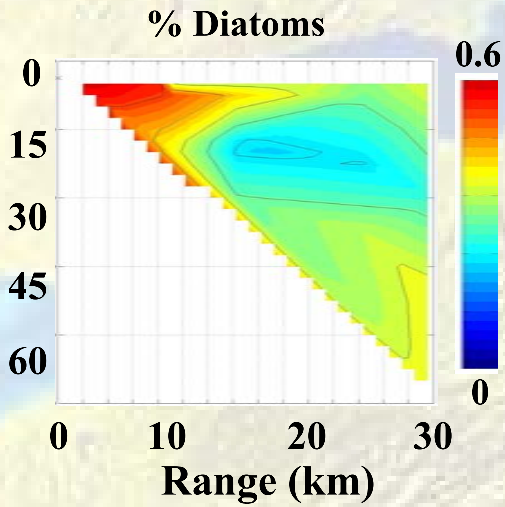


Optical Signatures of Phytoplankton Community Structure



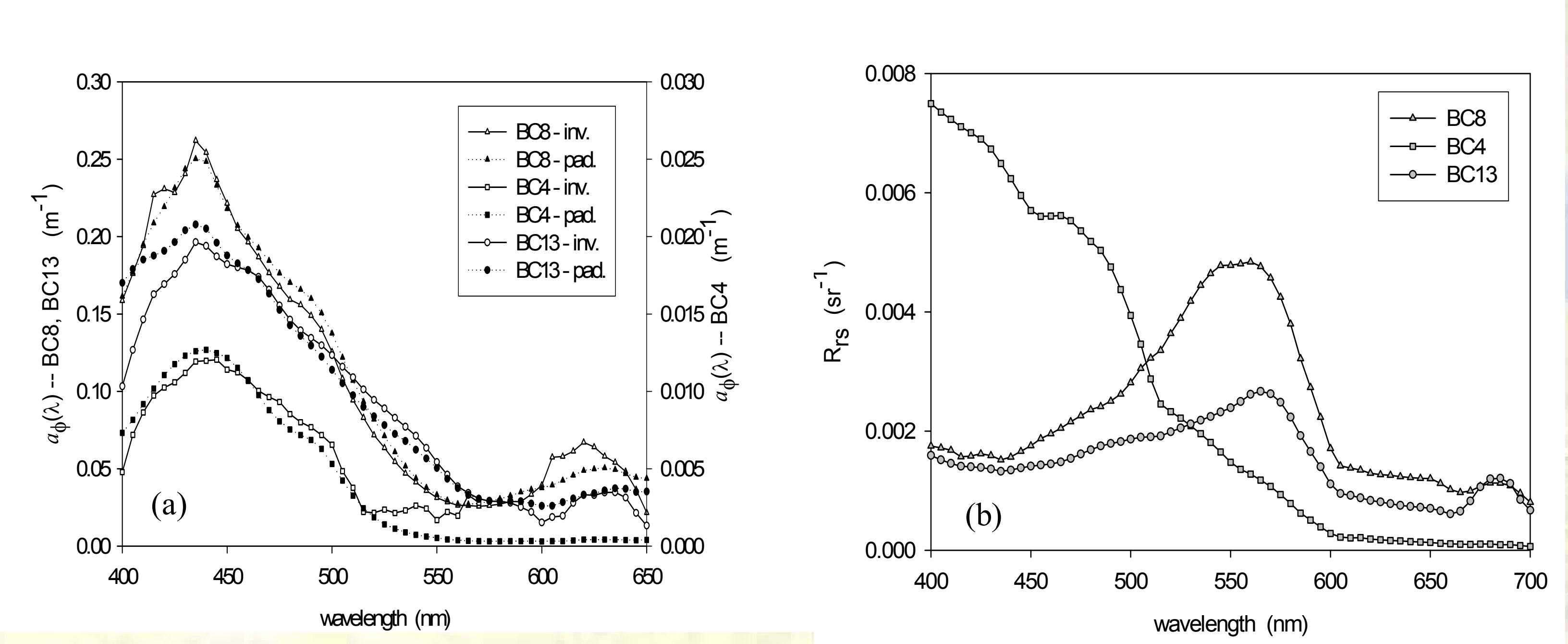






Optical Signatures of Phytoplankton Community Structure

- **Quasi-analytical algorithm to retrieve pigment absorption spectra that differ in correspondence with the type of phytoplankton present (Lee et al., 2002)**



Optical Characterization of Community Structure

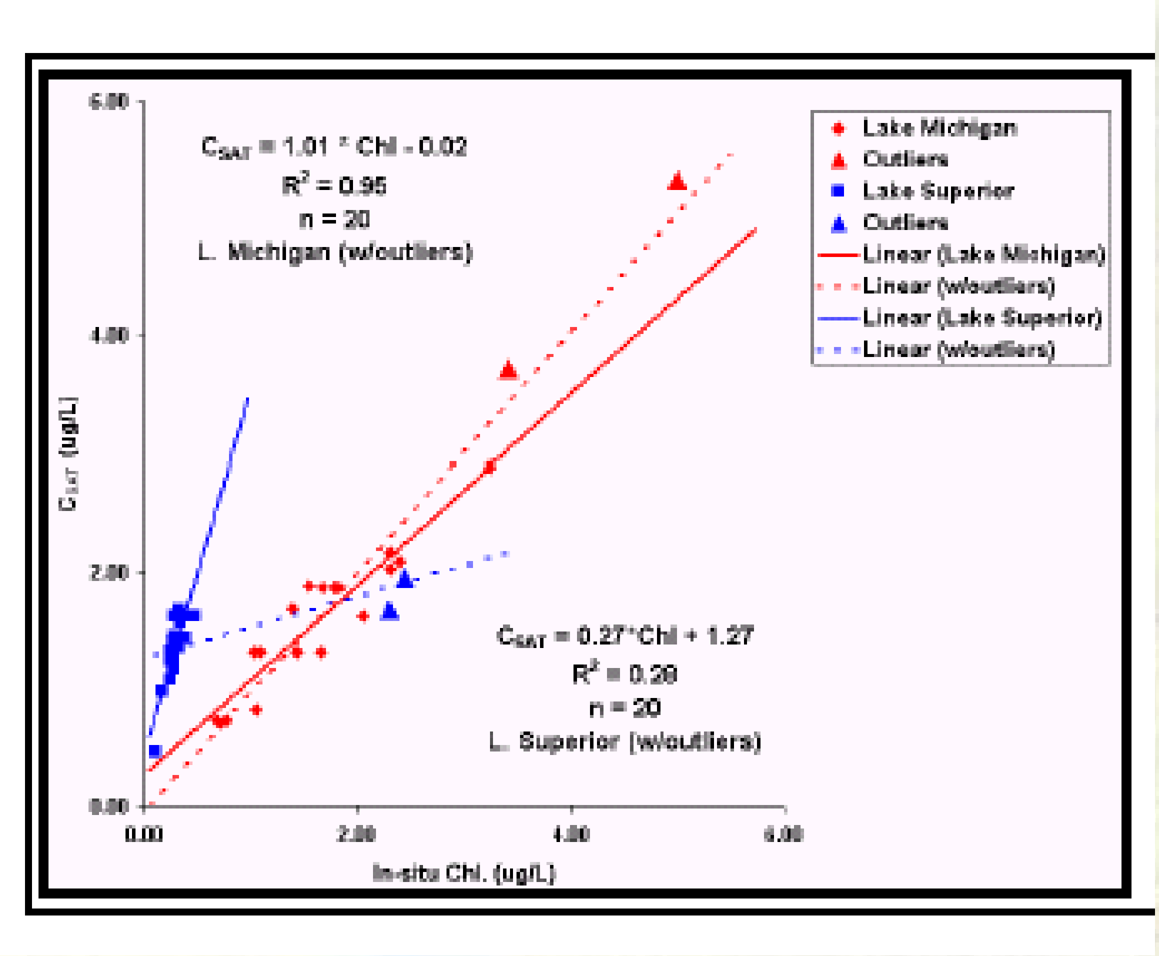
- **Array of optical sensors for characterizing community composition:**
  - Flow cytometry
  - Flowcam
  - Video Plankton Recorder
  - Others

Additional Themes to Consider

- Comparative Assessment of Lake Optical Properties and Development of Regionally Specific Algorithms
- Implementation of Optical Approaches in an Integrated Ocean Observing System for the Great Lakes

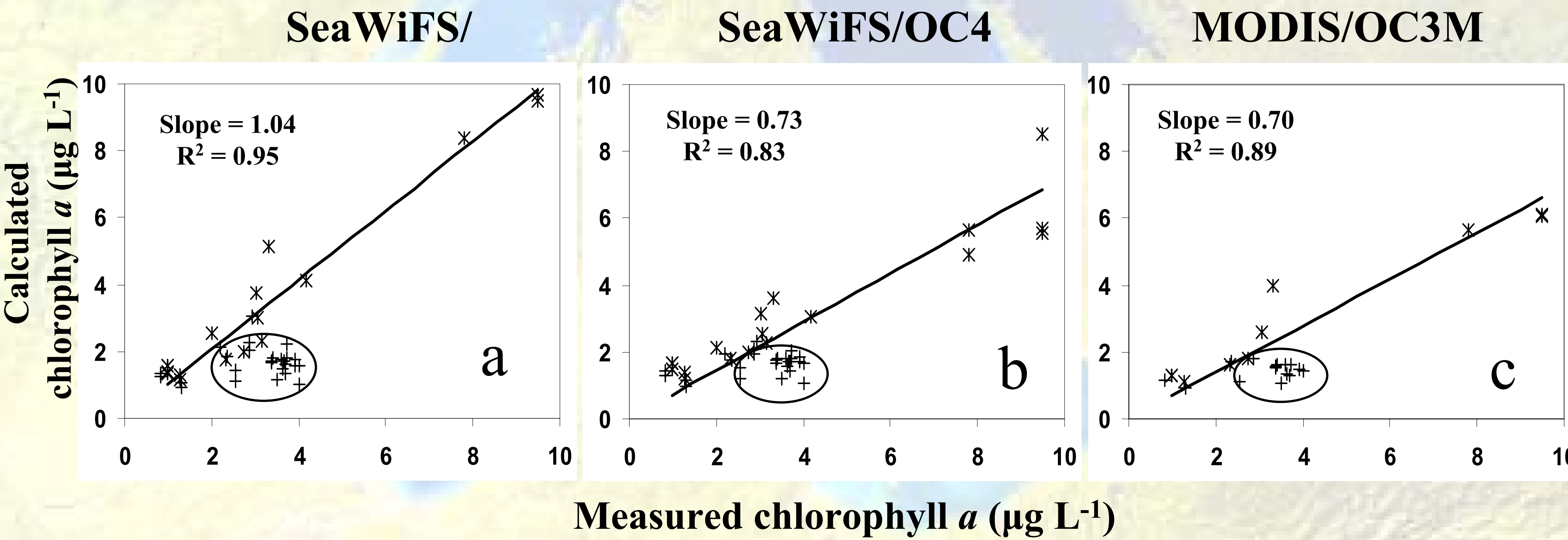
Comparative Assessment of Lake Optical Properties and Development of Regionally Specific Algorithms

- Marine chlorophyll algorithms seem to work well in Lake Michigan, but not in Superior (results provided by Judy Budd, MTU)



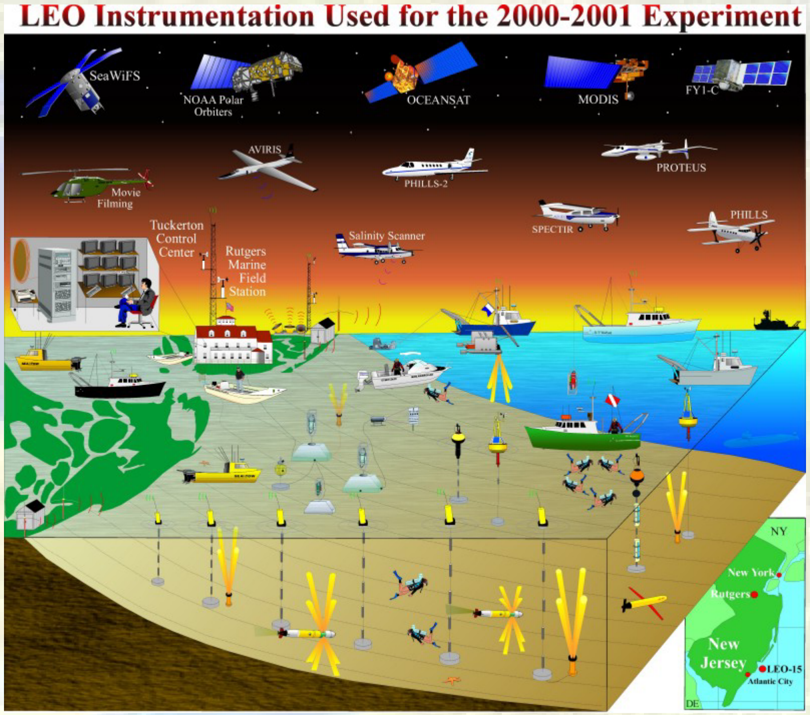
Comparative Assessment of Lake Optical Properties and Development of Regionally Specific Algorithms

- Cryptophyte absorption reduces reflectance at 555nm, resulting in an underestimate of chlorophyll using satellite algorithms



Implementation of Optical Approaches in an Integrated Ocean Observing System for the Great Lakes

- **The strength of optical approaches:**
  - ability to provide information about an extensive range of products
  - applicability of such measurements over a range of temporal and spatial scales
  - multiplicity of platforms from which optical instruments can be deployed



Summary

- **Suggested strawman themes:**
  - Transport and transformation of river-borne materials
  - Sediment transport dynamics and particle properties
  - Tracking the occurrence and evolution of algal blooms
  - Seasonal and interannual ecosystem responses to climate and meteorological forcing
  - Comparative optical assessment of the different Great Lakes
  - Implementation of optical measurement suite into integrated coastal observation network in the Great Lakes